Developing Site-Specific Eco-Risk Based Cleanup Goals for Total Petroleum Hydrocarbon (TPH) Contamination at Johnston Atoll

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Background

- JACADS (Johnston Atoll Chemical Agency Disposal System) Facility
  - 800 miles southwest of Hawaii
  - Incineration/destruction of 4 million pounds of chemical agents and weapons
  - Incineration completed November 2000
  - Multiple contaminants including petroleum

Background

- September 2002, EPA approved the Army's Revised Closure Plan
  - Green light to proceed with facility closure
  - Return JACADS to conditions safe for people, birds and marine life
- Closure plan includes petroleum hydrocarbon remediation

USFWS/Gerald Ludwig

Site-Specific Eco-Risk Based Total Petroleum Hydrocarbons (TPH) Cleanup Goals

- Cleanup criteria:
  - No mobile free product
  - Individual compound (BTEX and PAH) concentrations below cleanup goals
  - TPH below cleanup goals
- Ecosystem is the principle receptor:
  - Discharge of ground water to marine receptors
  - Direct avian exposure to contaminated soil

Site-Specific Eco-Risk Based TPH Cleanup Goals

- The challenge:
  - Develop site-specific eco-risk based cleanup goals for a mixture of hydrocarbons (TPH) in soil and ground water
    - Ground water cleanup goals to protect marine environment
    - Soil cleanup goals to protect ground water
    - Soil cleanup goals to protect direct eco-receptor exposure
    - Soil cleanup goals to protect direct human exposure
    - Soil cleanup goals to prevent product migration

Discharge of Groundwater to Marine Environment (Lagoon)

- Ground Water action level of 0.640 mg/l adapted from studies in San Francisco Bay
  - Mysidopsis bahia, invertebrate
  - The toxicity test used chronic exposure
  - Endpoint included sub lethal effect (growth)
  - Organisms exposed to fresh Jet Fuel rather than weathered (less toxic?) petroleum.

Discharge of Groundwater to Marine Environment (Lagoon)

- GW concentration data should be adjusted using a Dilution Attenuation Factor (DAF) to estimate GW concentrations at the shoreline.
- Issue:
  - Model is sensitive to DAF
- Resolution:
  - Consider range of DAFs
  - Further evaluate methods for determining DAF
  - Attenuation factor added to EPA DAF?
- Dilution attenuation factor:
  - DAF = 1 for locations $\leq$ 100 ft from shoreline
  - DAF = 1/distance for locations > 100 ft
-

$$DAF = \left(1 + \frac{Kid}{IL}\right)\exp\left[-kt_R\right] \qquad t_R = R\frac{L}{Ki}$$

Soil Cleanup Goals to Protect Ground Water

- Based upon site-specific synthetic precipitation leaching potential test
  - "worst case" leaching potential
- Relatively low solubility compounds
- Site specific Cleanup goal of 30,000 mg/kg in soil would not be expected to impact ground water above 0.640 mg/l
- The previous default TPH action levels was 5,000 mg/kg in subsurface soil

Synthetic Precipitation Leaching Procedure TPH Results

TPH Action Level Derivation Report, Johnston Atoll

Fractional Analysis

8015

Method	Analyte	Units	T49-TP101 11/13/03	T49-TP104 11/13/03
NWTPH-EPH	C10-C12 Aliphatics	mg/L	0.002 U	0.005 F
NWTPH-EPH	C10-C12 Aromatics	mg/L	0.007 F	0.069
NWTPH-EPH	C12-C16 Aliphatics	mg/L	0.010 U	0.013 F
NWTPH-EPH	C12-C16 Aromatics	mg/L	0.010 U	0.274
NWTPH-EPH	C16-C21 Aliphatics	mg/L	0.010 U	0.014 F
NWTPH-EPH	C16-C21 Aromatics	mg/L	0.010 U	0.121
NWTPH-EPH	C21-C34 Aliphatics	mg/L	0.010 U	0.011 U
NWTPH-EPH	C21-C34 Aromatics	mg/L	0.010 U	0.011 U
NWTPH-EPH	Total Extractable Petroleum Hydrocarbons	mg/L	0.071 F	0.495
NWTPH-VPH	C12-C13 Aromatics	mg/L	0.007 F	0.014 F
NWTPH-VPH	C5-C6 Aliphatics	mg/L	0.001 U	0.001 U
NWTPH-VPH	C6-C8 Aliphatics	mg/L	0.001 U	0.001 U
NWTPH-VPH	C8-C10 Aliphatics	mg/L	0.002 U	0.002 U
NWTPH-VPH	C8-C10 Aromatics	mg/L	0.003 U	0.003 U
NWTPH-VPH	Total Volatile Petroleum Hydrocarbons	mg/L	0.014 F	0.020 F
NWTPHGx	Gasoline-Range Hydrocarbons	mg/L	0.013 F	0.031 F
NWTPHDX	Diesel-Range Hydrocarbons	mg/L	0.477 J	5.51 J
NWTPHDX	Lube Oil Range Hydrocarbons	mg/L	0.309 F	0.284 F
NWTPHDX	Diesel-Range Hydrocarbons with SGCU	mg/L	0.054 U	0.693
NWTPHDX	Lube Oil Range Hydrocarbons with SGCU	mg/L	0.110 U	0.11 U
Total TPH Calc A (detects NWTPHDx + NWTPHGx)		mg/L	0.799	5.825
Total TPH Calc B (detects NWTPHDx SGCU+ NWTPHGx)		mg/L	0.1771[a]	0.8344[a]
Total TPH Calc C (detects NWTPH-EPH + NWTPH-VPH)		mg/L	0.085	0.515

Notes:

[a] Calculated assuming nondetects were present at the limit of detection.

mg/L = milligram per liter
SGCU = silica gel cleanup

U The analyte was not detected at the concentration listed.
J The analyte was positively identified; the quantitation is an estimation.
F The analyte was positively identified but the associated numerical value is below the reporting limit.

Soil Cleanup Goals to Protect Direct Eco-Receptor Exposure

- Fractional analysis of TPH to determine composition
- Eco-risk evaluated using fractional toxicity

$$ERBC = \frac{BW \times TRV}{\sum\left[\left(Frac_s \times DFI\right) + \left(Frac_p \times DFI \times B_{s/p}\right)\right] \times AUF}$$

$$Ecol.ActionLevel = \frac{1}{\left(1/ERBC_{ss}\right)_{frac1} + \left(1/ERBC_{ss}\right)_{frac2} + \ldots \left(1/ERBC_{ss}\right)_{fracN}}$$

where:
ERBC = Ecological risk-based concentration in soil (mg/kg)
TRV = Toxicity reference value (mg/kg body weight-day)
Fracs = Fraction of diet represented by incidentally ingested soil (unitless)
DFI = Daily ingestion rate of all food items (kg/day wet weight)
BW = Body weight of wildlife receptor (kg)
Fracp = Fraction of diet represented by prey (unitless)
AUF = Area use factor; fraction of home range occupied by site (unitless)
Bs/p = Soil-to-prey biotransfer factor (mg/kg per mg/kg wet weight)

Soil Cleanup Goals to Protect Direct Human Exposure

- Fractional analysis of TPH to determine composition
- Human risk evaluated using fractional toxicity

$$RBC = \frac{THQ \times BW_a \times ATN \times 365\ days/year}{EF \times ED_a \left[\left[\frac{1}{RfD_o} \times CF \times IR_a \right] + \left[\frac{1}{RfD_d} \times CF \times SA_a \times AF \times ABS_d \right] + \left[\left(\frac{1}{VF} \text{ or } \frac{1}{PEF} \right) \times Inh_a \times \frac{1}{RfD_i} \right] \right]}$$

ABSd = Skin absorption fraction (unitless)
ATN = Averaging time for noncarcinogens (years)
CF = Unit conversion factor (10-6 mg/kg)
EF = Exposure frequency (days/year)
IRa = Adult soil ingestion rate (mg/day)
RBC = Human health risk-based cleanup level for soil (mg/kg)
RfDo = Oral reference dose (mg/kg-day)
THQ = Target hazard quotient (unitless)
RfDd = Dermal reference dose (adjusted oral reference dose) (mg/kg-day)

AF = Soil-to-skin adherence factor (mg/cm2)
BWa = Adult body weight (kg)
EDa = Adult exposure duration (years)
Inha = Adult inhalation rate (m3/day)
PEF = Particulate emission factor (m3/kg)
RfDI = Inhalation reference dose (mg/kg-day)
SAa = Adult skin surface area exposed (cm2)
VF = Volatilization factor (m3/kg)

NAPL Mobility

- Residual non-aqueous phase liquid (NAPL) saturation calculated for Johnston Atoll soils

$$C_{res,soil} = ((\Theta_o \times \rho_o) / \rho_s) \times 10^6$$

$$\Theta_o = S_r \times \Theta_T$$

$$\text{Seepage velocity} = (k \times k_{LNAPL} \times \rho_{LNAPL} \times g) / (\mu_{LNAPL} \times n \times S_{LNAPL}) \times (dh_{LNAPL} / dl_{LNAPL})$$

$C_{res,soil}$ = residual NAPL concentration in soil

Θ_o = residual nonaqueous-phase volume fraction

ρ_o = density of chemical residual nonaqueous-phase liquid

ρ_s = dry soil density

Θ_T = soil porosity

S_r = fraction of residual nonaqueous-phase filled void

k = Permeability of porous media

k_{rLNAPL} = Relative permeability of the porous media to LNAPL

ρ_{LNAPL} = Density of the LNAPL

g = Gravitational constant

μ_{LNAPL} = Viscosity of the LNAPL

N = Porosity

S_{LNAPL} = Fraction of the pore space filled with LNAPL

dh_{LNAPL} / dl_{LNAPL} = LNAPL head, using LNAPL thickness in 3 wells

Soil Action Levels

- Multiple exposure pathways:
  - Groundwater protection 30,000 to 40,000 mg/kg
  - Direct soil contact by eco-receptors 73,000 to 161,000 mg/kg
  - Direct soil contact by human receptors.33,000 to 71, 000 mg/kg
  - Free product mobility 13,074 to 22,560 mg/kg

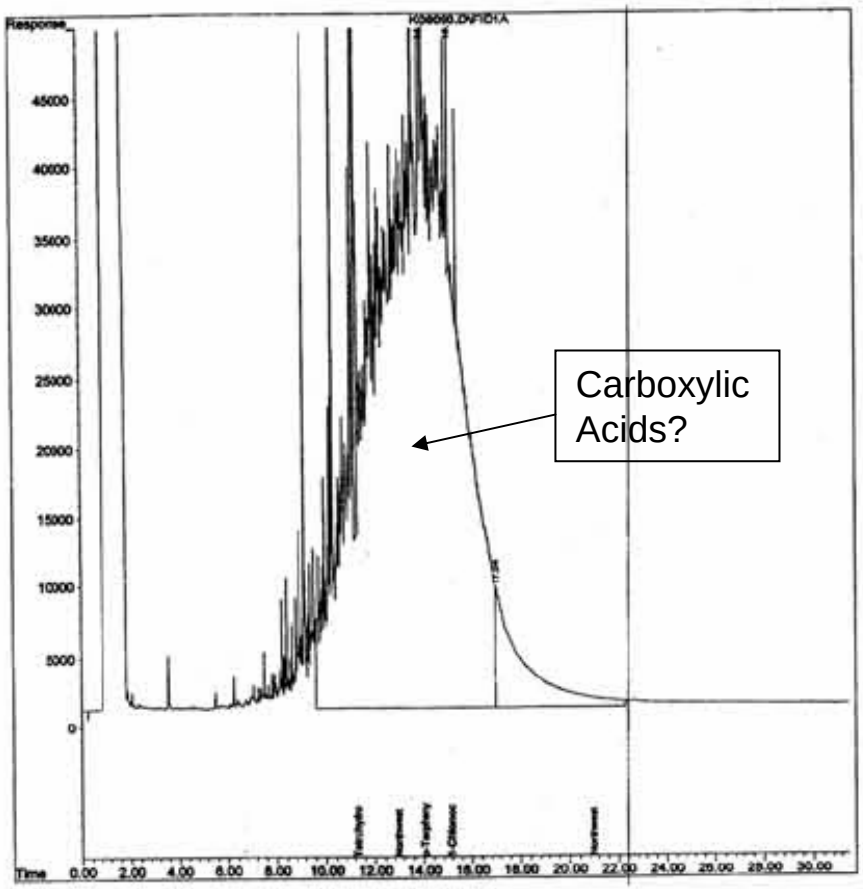
Soil Action Levels

- Soil Action level = 17,181 mg/kg based upon mobility limits (previously 2,000-5,000 mg/kg for surface/subsurface)

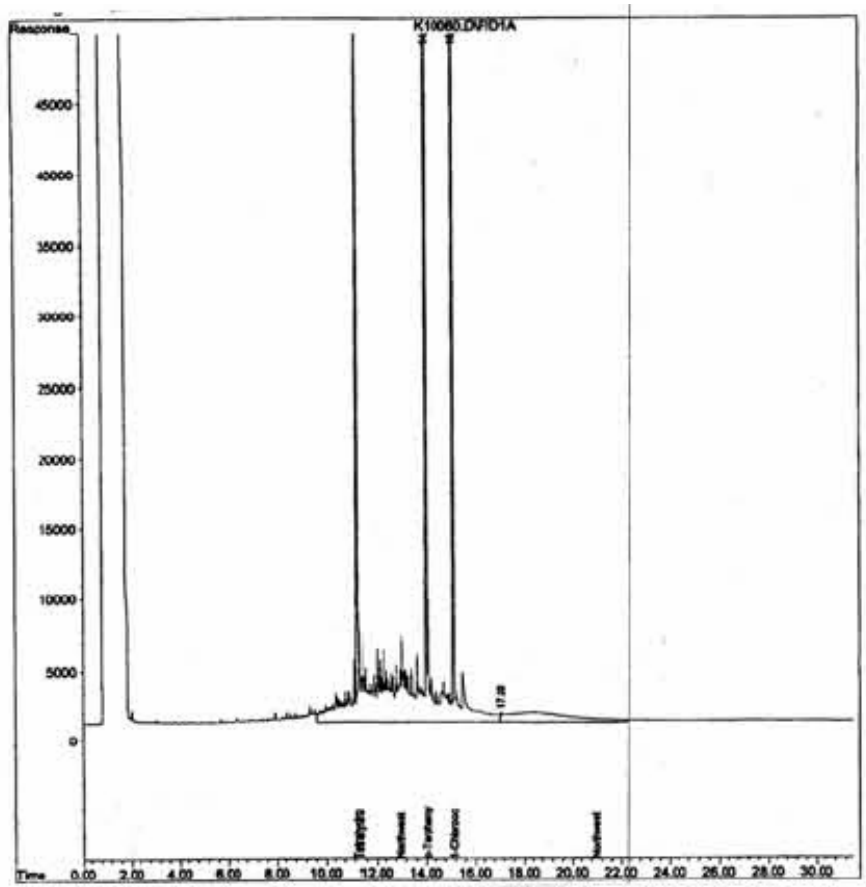
Other Issues

- Silica gel cleanup
- Disagreement between TPH concentrations measured fractional analysis and 8015
- Dilution Attenuation Factor

Silica Gel Cleanup



NWTPH-Dx without Silica Gel Cleanup



NWTPH-Dx with Silica Gel Cleanup

Disagreement Between TPH Analytical Methods

Sample	Units	Distance to Lagoon (ft)	*Dilution Attenuation Factor (distance/100)*	Total TPH A divided by DAF	Total TPH B (SGCU) divided by DAF	Total TPH C (fractionation) divided by DAF
FW-MW03D-1103	mg/L	1114	*11.14*	0.164	0.023	0.023
SWM-MW20-1103	mg/L	701	*7.01*	0.231	0.124	0.096
SWM-MW21-1103	mg/L	638	*6.38*	0.272	0.063	0.057
SWM-MW22-1103	mg/L	957	*9.57*	0.182	0.087	0.058
T49-FD1-1103[a]	mg/L	386	*3.86*	**3.060**	**1.036**	0.150
T49-MW15-1103	mg/L	386	*3.86*	**1.915**	0.515	0.140
T49-MW05-1103	mg/L	30	*1*	0.498	0.213	0.227
T49-MW06-1103	mg/L	306	*3.06*	0.444	0.487	0.332
T49-MW07-1103	mg/L	280	*2.8*	**1.940**	0.118	0.149

Notes:

[a] Field duplicate of sample T49-MW15-1103.

Bold and shading indicates value is greater than 0.64-mg/L action level.
Total TPH A = Sum of detected NWTPH-Gx, NWTPH-Dx diesel, and NWTPH-Dx lube oil
Total TPH B = Sum of detected NWTPH-Gx, NWTPH-Dx SGCU diesel, and NWTPH-Dx SGCU lube oil
Total TPH C = Sum of NWTPH-VPH and NWTPH-EPH.

mg/L = milligram per liter
SGCU = silica gel cleanup
TPH = total petroleum hydrocarbons

Conclusions

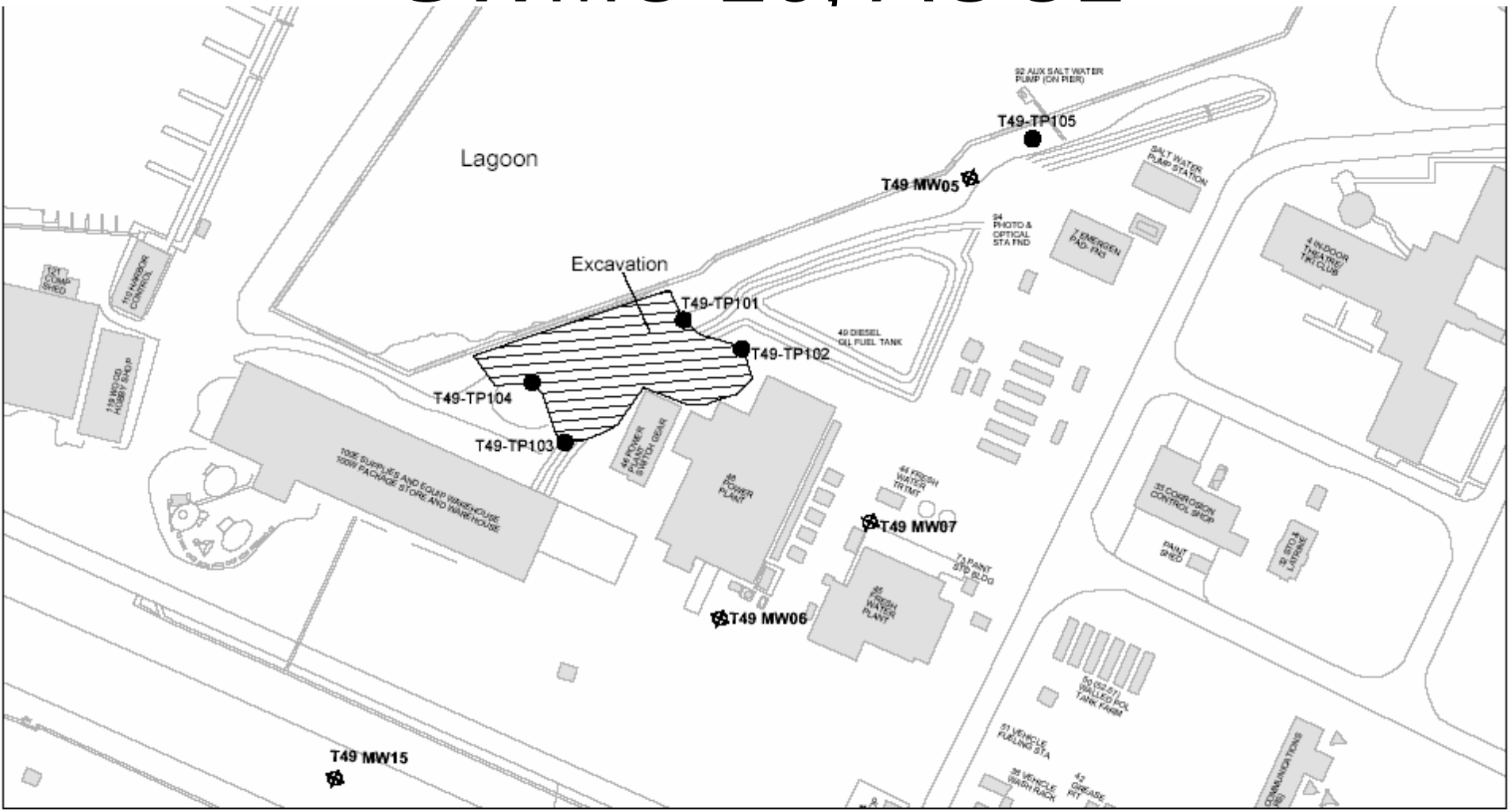
- Successfully developed site specific risk-based TPH clean up goals
- Helped move site toward closure safely and quickly
- Created model for future applications
- Identified questions for additional investigations

More Information

- EPA Region 9 JACADS Web Site

  http://www.epa.gov/region09/features/jacads/index.html

SWMU 16, AOC1



Legend

- Monitoring Well Sampled for TPH
- TPH Soil Sample (Test Pit)

N

0 25 50 100 150 200 Feet

Figure 3-1

TPH Sample Locations at SWMU No. 16/AOC No. 1

TPH ACTION LEVEL DERIVATION REPORT
JOHNSTON ATOLL